Reines and Rowland at 30: A tale of two Nobels

How two professors defined their fields, changed the world and won UC Irvine's first two Nobel Prizes in the same year.

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UC Irvine professors Frederick Reines (left) and Sherry Rowland (right).

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It was October 1995, and Leonard Cole had the news on. The anchor covered one story after the other, and then announced the winners of that year's Nobel Prizes.

Cole heard the anchor read a name: “Frederick Rains.” Cole thought nothing of it at first, but he knew that his cousin, Frederick Reines (pronounced “Rye-ness”), was a UC Irvine Department of Physics & Astronomy particle physicist who had long been expected to win a Nobel thanks to his co-discovery of one of the fundamental subatomic particles that comprise the universe, the neutrino.

That same day, Professor F. Sherwood Rowland of the UCI Department of Chemistry was at home in nearby Corona Del Mar. Alongside his postdoctoral research fellow, Mario Molina, Rowland discovered in 1974 that human-emitted chemicals could destroy stratospheric ozone and allow harmful UV radiation to reach the surface of the planet.

“I really thought Sherry was going to win the Nobel in 1990,” said Don Blake, Distinguished Professor in the UC Irvine Department of Chemistry who was one of Sherry Rowland’s first atmospheric chemistry graduate students. Year after year in October – the month the Swedish Academy of Arts and Sciences announces the recipients of that year’s Nobels – Blake would ask Rowland if he’d gotten the phone call. But each year, Rowland told him no, and, eventually, Blake stopped asking.

Then the fall of 1995 arrived. It was the morning of October 11, and Blake, who was getting ready for the day, didn’t hear it, but his phone was ringing. And somewhere else, Cole was listening to the news anchor mispronounce his cousin’s name.

Every university has stories of discovery that define it. UC Berkeley scientists discovered plutonium. A UCLA astronomer discovered the presence of a supermassive black hole at the center of our home Milky Way Galaxy.

UC Irvine has Frederick Reines and Sherry Rowland.

Reines and Rowland

Reines and Rowland were two of the founding faculty at the UC Irvine School of Physical Sciences. Rowland was the first chair of the UCI Department of Chemistry, and Reines was the first Physical Sciences dean.

A connection to the physical universe defined both men from an early age.

“The first stirrings of interest in science that I remember occurred during a moment of boredom at religious school, when, looking out of the window at twilight through a hand curled to simulate a telescope, I noticed something peculiar about the light; it was the phenomenon of diffraction," Reines, who was born on March 16, 1918 in Paterson, New Jersey, once wrote. "That began for me a fascination with light."

In high school, in response to a yearbook query to students about their ambitions in life, Reines wrote that he wanted "to be a physicist extraordinaire."

Meanwhile, Rowland, who was born on June 28, 1927 in a small town in Ohio called Delaware, spent his childhood years helping his high school science teacher operate the local weather station. "Our home was filled with books, and all of us were avid readers," wrote Rowland. "My reading at that time ran toward naval history, which was complemented with realistic scale-models and simulated naval battles using an elaborate mathematical system for rating each warship and the effects of combat on them."

Both men's paths continued unfolding. Reines discovered a passion for singing and theater in college, while Rowland became an avid athlete after a math teacher encouraged him to try his hand at tennis.

If you visit the two museum displays showcasing both Rowland and Reines' lives in the lobbies of the UCI buildings named after them, you'll spot a photo of a young Rowland in a baseball uniform along with his old baseball mitt, while across Physical Sciences quad in Reines Hall you'll find detailed notes Reines wrote about how proper breathing can help train a singer's voice.

Once on campus in the late 1960s, the two had the rare task of setting the tone for a brand-new school of science at a brand-new university. "Fred had the tough job of putting the departments together," said Blake. "And that included working with Sherry, who needed a lot of money to purchase our nuclear reactor."

Reines helped pave the way for Rowland, who was a radiochemist, to build the reactor, which still operates today in the basement of Rowland Hall.

By then, Reines had already redefined the field of particle physics by spotting something momentous: a ghost.

Project Poltergeist

Long before he came to UCI, Reines worked on the Manhattan Project – the top-secret government program led by Robert Oppenheimer known for creating the first atomic bomb. Reines moved with his wife, Sylvia Reines, to what was then called the “secret city.” Now the site of Los Alamos National Laboratory, the city is where the scientists involved with developing the bomb lived with their families.

Reines’ two children were born in the secret city while he worked on the theoretical physics behind the bomb under the leadership of the late Richard Feynman. While at Los Alamos, Reines, who was a baritone, was active in the Los Alamos Little Theater and the Los Alamos Light Opera, which included performances in Gilbert and Sullivan operettas. (To this day at UCI, there are scholarships in Fred and Syliva’s names supporting students in dance and theater.)

“Sylvia and Fred were a team, and few who knew them doubt that Sylvia was a driving force behind’s Fred’s success,” wrote Lisa Cowden, daughter of the Reines’ who also designed a stainless steel and word art installation called the “Reines Vista.” Dedicated to her father, you can find the artwork at the corners of California Avenue and Bartok Court in UCI’s University Hills neighborhood.

The Manhattan Project ended in 1947, soon after the end of World War II, and what followed was an age of intense optimism and faith in the power of science to reveal the inner workings of the universe and, in that way, create a better future for humanity. There was a galaxy of questions about the physical nature of the universe that researchers like Reines wanted to tackle. “Reines wanted to do big science,” said Henry “Hank” Sobel, an emeritus professor of physics at UCI and a former Reines graduate student. “They convinced the administration to let them do something fun.”

For Reines, that “something fun” was to go ghost hunting alongside his close collaborator, Clyde Cowan, who he met at Los Alamos after the Manhattan Project ended, in what the duo called Poltergeist Project. “Reines always looked for the important thing – something that would make a splash,” said Sobel.

The ghost Reines and Cowan wanted to find was a theoretical subatomic particle called the neutrino. Physicists call it the ghost particle because it has the strange ability to simply pass through most of the matter it encounters. Indeed, a neutrino can pass through lead for an entire light year before it interacts with another particle.

“Everyone said it would be impossible to detect a neutrino, and that was exactly why Reines wanted to try,” said Sobel.

All matter in the universe is made of particles, including familiar particles like electrons, neutrons and protons. But those aren't the only particles that comprise the cosmos. Other particles include photons – the particles that comprise light – as well as particles that have never been observed directly, but which physicists theorize exist.

There's also a short list of forces physicists use to describe the way the universe works. These forces have names like the strong force and the weak force, as well as gravity. The forces are measurable in the way the particles that comprise the universe behave with respect to each other. Most neutrinos, by contrast, extremely rarely interact with other particles – they simply float through other objects as they zoom through the universe in every direction at nearly the speed of light. Indeed, every second, billions of neutrinos pass through your body, emerging from sources like the nuclear reactions that power the sun and supernova explosions.

For the most part, neutrinos pass through all other matter. But every now and then, a neutrino, as if curious to see what it's like to mingle with other particles like electrons and neutrons, will emerge from its ghostly realm and interact with other particles.

It was those neutrinos Reines and Cowan wanted to detect.

The pair first tried to detect the particle at the former Hanford Site – a federal nuclear site in Washington state. Theory suggested that nuclear processes generated neutrinos through a process called beta decay, wherein the neutrons in atomic nuclei transform into a proton, electron and a neutrino.

But there was a problem: cosmic radiation from space was making it impossible for Reines and Cowan to detect any neutrinos that may be there, and they realized they needed a detector that was shielded from cosmic rays. They found such a detector at what is now the Savannah River Site – a U.S. Department of Energy facility in South Carolina. There, shielded from cosmic rays, Reines and Cowan collected data with a detector made out of two giant tanks of water. The duo, during what are now called the Cowan-Reines experiments, detected the first neutrinos at the Savannah River Site and published their results in 1956 in *Science.*

Enduring Impact

Reines founded the particle physics research group in the UCI Department of Physics & Astronomy, and its members include a long list of scientists whose research is, either directly or indirectly, a downstream result of the work Reines and his colleagues did.

That includes the work of Sobel, who in the 1960s was part of the team that helped establish the existence of atmospheric neutrinos – neutrinos generated when cosmic radiation interacts with our planet's atmosphere – by venturing deep underground into a gold mine in South Africa. Sobel was also one of the lead scientists behind the Super-Kamiokande neutrino detector in Japan, which helped establish that neutrinos have mass.

Another professor carrying on Reines' legacy is Tim Tait, whose work deals with the hunt for dark matter – matter physicists suspect exists, but which they've yet to directly detect. "For me, Fred Reines is the inspiration that keeps me going on my research path," Tait said. "Fred's long and ultimately successful quest to detect neutrinos is a direct analogue to my own efforts to understand what the nature of the dark matter that fills our universe is."

Tait added that, while there are no guarantees dark matter particles will be detected anytime soon, Reines' legacy shows that taking decades to build increasingly sensitive detectors can pay off.

UCI's Professor Pedro Ochoa-Ricoux, whose group studies neutrinos, is another Reines torchbearer. "The techniques that he and Cowan pioneered to detect neutrinos remain foundational to our work today," said Ochoa-Ricoux. "Many of the detectors we've recently designed and built follow strategies remarkably similar to those Reines established over half a century ago. The main differences are that today's detectors are larger and take advantage of modern technologies. In fact, some of us are actively working to build on that foundation to develop an entirely new class of neutrino detectors."

Elsewhere, UCI's Professor Mu-Chun Chen studies neutrinos to answer a prominent question: in the universe, why is there more matter than antimatter? "Reines' discovery of the neutrino opened up a broad range of research programs," said Chen. "I have been studying the properties and interactions of neutrinos, and their signatures both in particle physics experiments and in cosmology."

Discoveries by those at UCI like Sobel demonstrated that neutrinos have mass, which, Chen explained, is an important part of solving the antimatter question. “It’s a key problem my research is trying to answer,” she said. “Why is there more matter than antimatter in the universe? Neutrinos are part of the key to answering that question.”

And the hunt for other new particles is still happening. UCI’s Professor Jonathan Feng is leading a team of physicists that, in 2020, finished building a detector called FASER that, installed at CERN in Geneva and Switzerland, may for the first time detect the first direct evidence for particles just as elusive as the neutrino once was: dark matter photons, which, if found, would confirm the existence of another kind of ghost particle that pervades the cosmos.

It’s a hunt that’s riding the wave started by Reines and Cowan.

Rowland and Molina Throw Fat in the Fire

In 1974, Sherry Rowland, alongside his postdoctoral research fellow Mario Molina, discovered that human-emitted chemicals can decrease stratospheric ozone – something that lets harmful UV radiation reach the surface of the planet.

One thing about the discovery, though, is that it almost didn’t happen. Rowland was a radiochemist by training and didn’t have much of an interest in the chemistry that would, unbeknownst to him, reveal beyond a shadow of a doubt that human activity was responsible for the formation of a hole in the ozone layer in our planet’s upper atmosphere.

But when a young photochemist from Mexico named Mario came to work in Rowland’s lab as a postdoctoral fellow, the story started to take shape. Molina was at UCI to do research in photochemistry, and Rowland gave him a list of three different unanswered questions that he thought may be interesting.

Molina was interested in how light catalyzed chemical reactions in the air, so he picked the project dealing with questions about what happened to human-emitted chemicals called chlorofluorocarbons (CFCs) – which at the time was a common emission from everything from hairspray cans to refrigerators.

“Shining light on stuff is what Mario did,” said Blake.

Rowland first got the idea to study CFCs and their behavior in the atmosphere after attending a conference in Florida where another scientist, James Lovelock, presented data about CFCs in the atmosphere. Rowland always took scrupulous notes, and he jotted down what Lovelock said.

At the time, no-one thought CFCs might be a part of the ozone problem. “CFCs were supposed to be inert,” said Blake. “At least that’s what the chemical companies said.”

Molina performed experiments where he shined light on samples of air containing CFCs, and found that, in the UV light pervasive in Earth’s stratosphere, CFCs catalyze the breakdown of ozone.

“Those two, Mario and Sherry, they were not in the field,” Blake said. “They had no clue, unlike scientists who set out to find a cure for cancer. These guys just stumbled into it. Sherry was just a curious guy. He had no thought in that moment that this would save the world.”

In his office in Rowland Hall, Blake wrote out the chemical formulation describing what Rowland and Molina found.

The reaction only takes a few lines to complete:

$CClF_2 + h\upsilon \rightarrow CClF_2 + Cl$ (1)

$Cl + O_3 \rightarrow ClO + O_2$ (2)

$ClO + O \rightarrow Cl + O_2$ (3)

C is carbon, Cl is chlorine, F is fluorine, hυ is a photon, O is oxygen. The chlorine from reaction 3 can then go back to reaction 2 and destroy more ozone. Chemists call this a catalytic cycle.

“That is a Nobel Prize,” Blake said, motioning to the formula on the whiteboard. “It was elegant, it was simple, and I think that that is something that isn’t emphasized enough. That it was two people from a different field. It would be like if you liked to surf and you come out of the water and there’s a rock or something in your way, and you pick it up and you hear it hissing, and you take it home and it turns out it sucks up CO_2. You could save the world right now. That’s what their work meant.”

When Rowland returned home after realizing what CFCs were doing in the upper atmosphere, his wife Joan Rowland asked him how work had been. “It’s going really well,” he said. “The only trouble is, I think it’s the end of the world.”

Rowland and Molina's discovery lit a fuse that would, eventually, bring world governments together to formulate the Montreal Protocol – an international treaty meant to prevent the depletion of the ozone layer. But it came at a cost: Rowland received negative attacks in the press likely stemming from industry pushback against his work, and personal threats that included accusations that the CFC story was a ploy sowed by Russian spies.

Many criticized Rowland for overstepping his bounds as a scientist to issue public policy recommendations. “I recommended that we quit putting this material into the atmosphere,” Rowland told the *San Jose Mercury News* in October of 1995, “and that put the fat in the fire.”

Molina and Rowland published their results in *Nature*, and at first saw little to no response from politicians or the public on the clear action that needed to happen.

So, the two became champions of their own science. They presented their results at conferences, public gatherings and testified in front of Congress.

“If not now, when? If not us, who?” Molina said in an interview for the book *Partnering* by Jean Oelwang.

Through the storm, Rowland frequently credits the support of his wife, the late Joan Rowland, who was an ardent supporter of the School of Physical Sciences, for helping him persist in championing his and Molina’s findings. “She has been a knowledgeable and trusted confidante through all the last two decades of ozone research,” Rowland wrote in his biography for the Nobel Prize.

Eventually, he and Molina’s science prevailed. CFC use dropped dramatically, and the ozone hole began closing.

“Rowland invented a new kind of science, and we will never look at the world the same way again,” said Susan Trumbore, professor of Earth system science at UCI in an interview with Oelwang. “Because of Rowland and a few others like him, globalism is a natural concept to scientists of my generation.”

Legacy

Reines knew that every physicist who had discovered a subatomic particle had gone on to win a Nobel Prize. But by the time the 1980s hit, Reines still hadn't gotten the call – even after another team of physicists received a Nobel for research dealing with the neutrino – and hope seemed dim.

"He was a little depressed," said Blake, who was Reines' neighbor at the time in the University Hills neighborhood adjacent to campus. Blake recalled how Reines' cognitive health had been in decline for some time by the time he received the Nobel news.

That day in October 1995, when Leonard Cole heard the news anchor describe how "Frederick Rains" had won a Nobel for his work to detect the neutrino, Cole felt a surge of excitement once he realized his cousin had finally won the prize. In the days and weeks after Reines learned he'd won the Nobel, Blake remembers how he regained his clarity to the point where he was almost his old self. At the ceremony in Sweden, Blake recalled, Reines joined and sang with choirs.

As for Rowland, you can find his legacy writ large, both at UCI and around the world.

"I don't think there were many universities that conducted atmospheric chemistry research prior to the ozone research," said Blake. "But once Sherry and Mario's *Nature* paper came out, that changed. Because it was an international problem, it changed university research not just in the U.S., but in Europe and Asia. For perhaps the first time, there were international meetings on different areas of atmospheric sciences."

These days, the UCI School of Physical Sciences is an internationally renowned hotbed of research into all manner of atmospheric chemistry-related questions. Most recently, a cross-campus research initiative helmed by Professor Barbara Finlayson-Pitts of the AirUCI research unit is seeking to understand how emissions from vehicle braking may be creating a public health crisis.

Rowland was also the first to breathe life into the UC Irvine Nuclear Reactor Facility, which Professor Sarah Finkeldei now leads as she conducts research ranging from nuclear waste disposal to nuclear energy and cancer treatment development. "Sherry Rowland's work at the university changed the way we see the world, and getting to address issues related to global energy demands in the same facilities he helped build is highly inspiring," Finkeldei said.

As for Blake, he's fully aware of the impact Rowland has had on his life. "That's simple," said Blake, whose own research helped reveal that concentrations of the greenhouse gas methane in the atmosphere, rather than holding steady, are increasing because of human activity. "I wouldn't be anywhere close to where I am now without the field of atmospheric chemistry and 34 years of guidance from Sherry."

Rowland's office is still at the school. If you climb the stairs or take the elevator to the fifth floor of Rowland Hall at the School of Physical Sciences and follow the office numbers to 571, you'll see his name printed there: Professor Sherwood F. Rowland. In another age, you could knock on the door, and the person who opened it would cut a unique figure: six feet five inches tall, mutton chops and a warm smile.

Many variables had to come together in the right way for Rowland and Molina's ozone science to happen – but perhaps the most important ingredient, Blake thinks, was Rowland's character. Rowland had a very kind, approachable presence that created a research culture in his lab where it was okay to ask questions or make statements about your science that may not be completely correct right off the bat.

"His kindness was a constant," said Blake.

Those who knew Rowland and Reines knew they would often get lunch together in Aldrich Park, and they say they can sometimes almost see the two walking back to the School of Physical Sciences, Sherry grinning in his kind way and Fred humming a tune as they climb the steps between the two buildings that now carry their names.

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